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A Li-ion Battery Management System Based on MCU and OZ8920

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Abstract

A management system based on MCU and OZ8920 chip for Li-ion battery series has been developed in this paper. It is successful in solving the defects in design of OZ8920 chip cascade and accomplishing I^2C bus communication between MCU and OZ8920 chip. It has several significant functions in this design, which is combined with 16 series connected cells, such as charge and discharge protection, single cell voltage and temperature monitoring, cell pack balance, etc.

Keywords: battery management system; OZ8920; I^2C bus communication; protection circuit

1. Introduction

Li-ion battery has become the most widely used chargeable battery because of its advantages, such as higher voltage level, higher energy density, no memory effects and no pollution to the environment [1]. Li-ion battery packs of multi cells in series, which provide a high-voltage power supply, have become more and more popular in many applications, e.g. hybrid electric vehicles, electro motors, etc. However, for more powerful supply voltage, the cell number is increased and the voltage rises as well. Battery management for battery packs composed of multi cells is quite different from single cell applications, and thus challenges arise. The information of each battery must be acquired and processed to ensure the safety operation of every single cell and improve performance of the whole battery pack. Estimation on state of

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charge (SOC) and monitoring the battery characteristics have always been important parts in battery management research [2]. High performance battery management system (BMS) is able to allow the cell work in the best performance [3]. BMS can improve the battery's performance and extent its working life through the real-time battery state monitoring and battery SOC estimation [4, 5]. BMS can be classified into two groups by types of realization: one is based on programmable smart chip; the other is based on discrete device.

This paper proposes a new battery management system, which is based on the MCU and OZ8920 chip. This system can be applied to data acquisition, state estimation of battery, balance control, heat management, data communication and fault diagnosis for the battery pack.

2. The design of BMS using chip cascade

OZ8920 is a highly integrated battery pack protection and monitor IC for managing Li-ion or Li-polymer pack in electric bicycle, electric motorcycle, power tools, and UPS applications. It supports 5-8 series Li-ion battery pack or Li-polymer battery pack applications [6].

The battery pack consisting of more than 8 Li-ion batteries in series needs multi-OZ8920 chips to manage it. And the chips are connected with cascade. According to the datasheet of OZ8920 chip, if we need multi-chips cascade to manage, taking two chips cascade for example, its structure is shown in Fig. 1. (a). The design achieves that two OZ8920 chips cascade control 15 series Li-ion batteries. In this design, the two cascade chips share the eighth battery B8 and achieve the transfer of cell bleeding parameters. I^2C bus interface connects OZ8920 adapter and the OZ8920 adapter is used to set the protection parameters in EEPROM. If the parameter values of battery pack exceed the parameter values that we set, the chips will automatically protect the battery pack to ensure it working well. This design of cascade has the following three drawbacks:

- As sharing the B8, it could manage no more than 15 series Li-ion cells.
- The condition of cell bleeding is that single cell voltage of the battery pack should be higher than the threshold V_{T1} and voltage difference of two single cells should be higher than the threshold V_{T2}. Because the eighth battery B8 is shared by two chips, the largest voltage difference of battery pack is twice as much as that of the 8 batteries connected by one OZ8920 chip when the voltage of the eighth battery (VB8) is the highest among batteries numbered 1 to 8 and it is also the lowest among batteries numbered 8 to 15 at the same time,. So when cell bleeding, the accuracy of bleeding using two chip cascade doubles compare with that of the single chip. Especially, when the multi-chips are cascaded, threshold parameters deviation will be bigger.
- Two I^2C bus interfaces emerges, and the chip needs to be programmed twice. It is cumbersome to operate and inefficient.

3. Hardware design of BMS based on MCU and OZ8920

In order to overcome those drawbacks above, this paper presents the design of battery management system based on MCU and OZ8920. This design includes power module, voltage converting circuit module, MCU of C8051F series, data acquisition module, ALT signal coupling circuit, I^2C bus coupling circuit and master control protection circuit. Its structure is shown in Fig. 1. (b).

In this design, the ALT signal is used to produce the interrupt signal and wake up the MCU to read the data of OZ8920 chip. And then MCU judges the safety events which cause the interrupt. The signal ground voltages of two OZ8920 chips are different (one is the negative of B1, the other is the negative of B9), so when the data is transmitted in I^2C bus, a signal transmission circuit is needed to realize the vertical coupling of different signals.

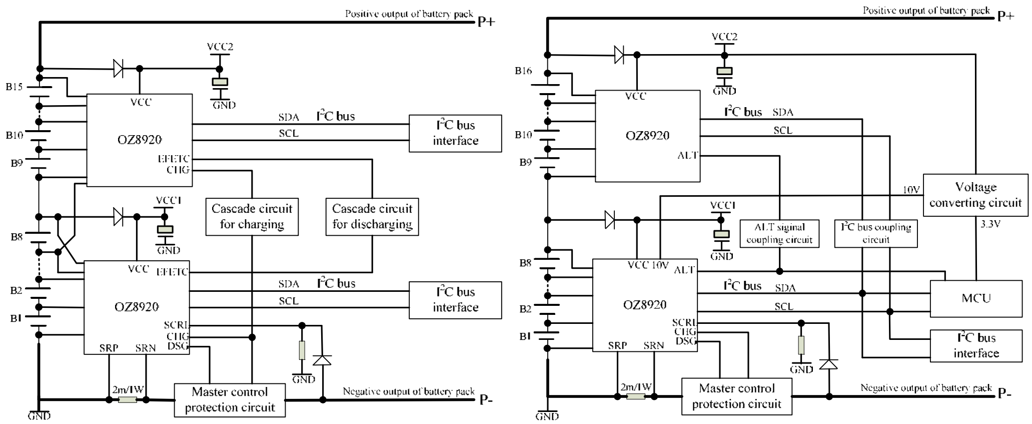

Fig. 1. (a) The structure of two chips cascade; (b) The hardware structure of BMS based on MCU and OZ8920

3.1. Common design of coupling circuit

When designing coupling circuit, we should take switching rate and power consumption into account. The circuit design with lowest power consumption is the best only when the switching rate can meet the requirements of signal transmission. Common circuit designs mainly use opt-coupler and magnetic coupling. Opt-coupler includes low speed opt-coupler and high speed one.

The low speed opt-coupler has low switching speed and can’t meet the requirement of signaling rate. Taking PC817 for example, from the switching characteristics of it [7], we can know that the typical rise time is 4us and the typical fall time is 3us, so the switching speed is about 50 KHz and can’t meet the requirement of signaling rate.

The high speeding opt-coupler has large power consumption despite the switching speed meet the requirement. Taking 6N138 for example, from the switching and electrical characteristics of it [8], we can see that the typical rise time is 1us and the typical fall time is 0.2us, but the forward current is 12mA, so the current consumption is bigger although the switching speed can meet the requirement.

In recent years, the rise of magnetic coupling with advantages of high-performance, low power consumption and long life can realize 150Mbps high-speed separation. Taking ADuM1250 for example, from the switching and electrical characteristics of it [9], we know that the switching speed is 1000 KHz. When the input voltage is 5V, the working current of the device is 2.8mA; while the input voltage is 3.3V, the working current I_Q is 1.8mA. On the assumption that the pull-up resistance of I^2C bus, when the signal is transmitted in the same probability, the sum working current is:

$$I_{SUM} = 2\times\left(I_Q + \frac{3.3V}{10K\Omega}\times 50\%\right) \approx 4mA \tag{1}$$

So the power consumption is large, and the coupler is in high price.

In order to overcome the above defects in common design of coupling circuit, this paper puts forward the design of I^2C bus coupling circuit.

3.2. Design of I^2C bus coupling circuit

The I^2C bus coupling circuit is shown in Fig. 2. It can transmit the level signal by the switch characteristics of triode. The signal is almost no distortion, at the same time, the power consumption is very small.

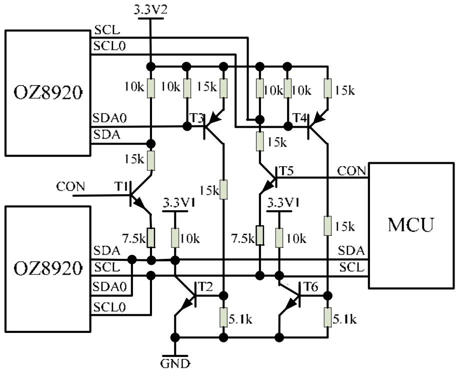

Fig. 2. The I^{2}C bus coupling circuit

As shown in Fig. 2, SDA0, SCL0 is the signal output pin; and SDA, SCL is the signal input pin, meanwhile, the CON pin is used for communication between CPU and OZ8920 located in up.

When the OZ8920 located in up transmits the data by I^{2}C bus to the MCU, T1 and T5 are cut off, and the SDA0, SCL0 signals of OZ8920 are transmitted through T2, T3, T4, T6 to the SDA, SCL pins of the MCU. The SDA0 signal waveform of OZ8920 and SDA signal waveform of MCU are shown in Fig. 3. (a). When the MCU transmits the data by I^{2}C bus to the OZ8920 located in up, T2, T3, T4, T6 are cut off, and the SDA, SCL signals of MCU are transmitted through T1, T5 to the SDA, SCL pins of the up OZ8920 chip. The SDA signal waveform of MCU and SDA0 signal waveform of OZ8920 are shown in Fig. 3. (b). Known by the waveform, the rising and falling edges of the receiving signal are less than 1us and can transmit the signal successfully, meanwhile, the waveforms are almost no distortion.

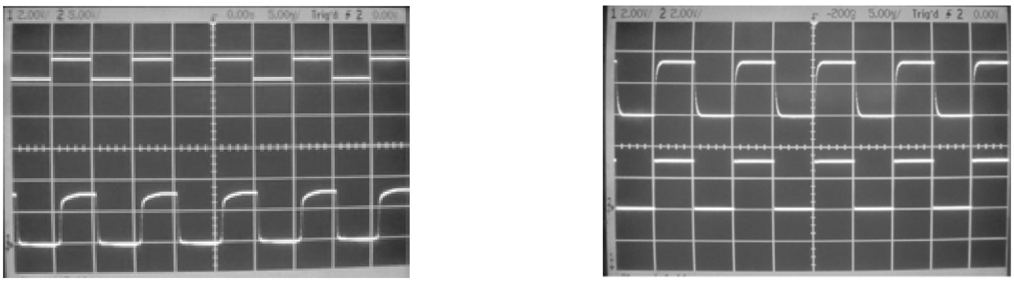

Fig. 3. (a) The SDA0 signal waveform of OZ8920 (down) and SDA signal waveform of MCU (up); (b) The SDA signal waveform of MCU (up) and SDA0 signal waveform of OZ8920 (down)

In this design, there is no current loop and the current I_{H} consumption is approximately to zero when the transmission signals are in high level. When the transmission signals are in low level, the current I_{L} of each branch is:

$$I_{\mathrm{L}} = \frac{3.3\mathrm{V}-0.7\mathrm{V}}{15\mathrm{K}\Omega} + \frac{3.3\mathrm{V}}{10\mathrm{K}\Omega} + \frac{3.3\mathrm{V}-0.7\mathrm{V}}{7.5\mathrm{K}\Omega} = 0.85\mathrm{mA} \tag{2}$$

When the signal is transmitted in the same probability, the sum working current I_{SUM} is:

$$I_{\mathrm{SUM}} = 2\times(I_{\mathrm{H}} + I_{\mathrm{L}})\times 50\% = 0.85\mathrm{mA} \tag{3}$$

To sum up, the current consumption of I^2C bus coupling circuit is only about 40% of magnetic coupling circuit. So the I^2C bus coupling circuit is more efficient than the design of opt-coupler and magnetic coupling in terms of switching rate and power consumption.

4. Software design

The software design of BMS mainly consists of program modules, such as the initialization module, the main program module and the interrupt function caused by safety event.

4.1. The initialization module

The initialization module includes: initialization, timer initialization, port initialization, external interrupts initialization and OZ8920 chip initialization. What should be noted here is that we should set the priority of System Management Bus interrupt at high level.

4.2. The main program module

The main program module comprises the following three parts: configuring the operation register of OZ8920 chip enabling the scan event and charger/discharger FET, configuring the sleep event register enabling sleep event, configuring the power control register enabling MCU to be in idle mode.

4.3. The interrupt function module

The interrupt function module, which is the core part of the design of software, mainly includes judging the safety event and clearing the event flag after completing the protection, judging the state of charge and discharge, sampling the single cell voltage and judging condition of cell bleeding. The software flow chart is shown in Fig. 4.

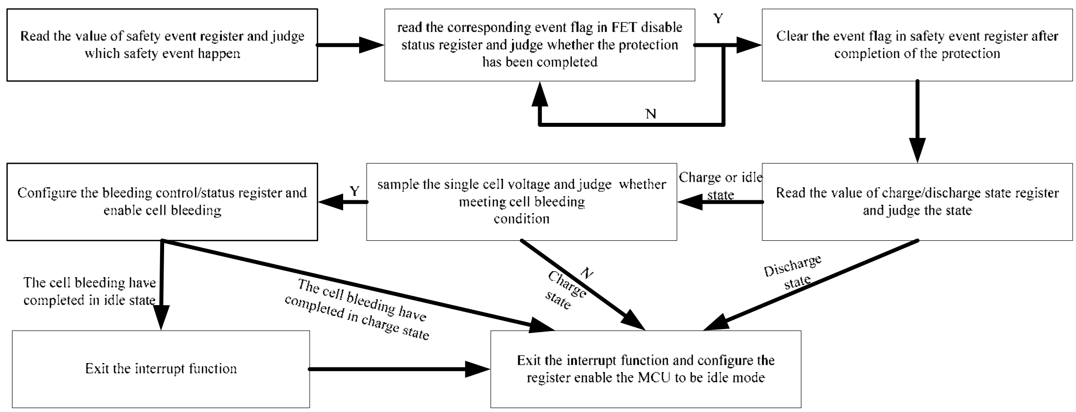

Fig. 4. The software flow chart

5. Conclusion

This paper firstly analyses and studies the drawbacks BMS based on OZ8920 chip cascade design, and propose the BMS based on MCU and OZ8920. The system can succeed in managing the battery pack of

16 series Li-ion using two OZ8920 chips. When cell bleeding happens, the bleeding accuracy of BMS based on MCU and OZ8920 is the same with the accuracy managed by a single chip, so the bleeding error is decreased compared with chip cascade design. The design of battery management system based on MCU and OZ8920 chip realizes the signal parameter passing with I^2C bus coupling circuit reducing power dissipation, and programs the two chips directly through I^2C bus saving the bother of twice programming through chip adapter. The system sets MCU to enter idle mode after the completion of the initialization, which can greatly reduce system power consumption, using external interrupt to wake up MCU generated by the ALT signal. This proposed design enhances the reliability and maintainability of system with high performance, low cost and power consumption, achieving good result in practical use.

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